CALIFORNIA AGRICULTURAL EXPERIMENT STATION · THE COLLEGE OF AGRICULTURE
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WATER SPOT OF NAVEL ORANGES:

STUDIES OF THE PROBLEM TO 1948

This Publication Is . . . A SUMMARY of what is known at the present time, in the fall of 1948, about the important problem of water spot of navel oranges . . . AND A PROGRESS REPORT on the research program which has been and still is under way.

● From 1927, when the initial surveys were made, to 1948, continuous experimentation has been under way, first, into the nature of water spot and its causes; then into the relationship of pest control measures to water spot; into the effect of other cultural practices upon the resistance of oranges to water spot; and more recently to find substitutes for oil sprays which will control pests without increasing the susceptibility of fruit to water spot.

● Final answers have not yet emerged. Further work with some of the new insecticides will prove whether or not these materials can be substituted for oil sprays. If they can, or if biological control methods for scale insects are found, water spot should become a much less serious problem. If they cannot, additional research will be needed to find some other corrective measures.

● Meanwhile, a good deal of information has accumulated; and a number of suggestions are offered. These may prove helpful pending more positive answers.

Distribution of Water Spot

Water spot of navel oranges causes important losses in eastern Los Angeles and western San Bernardino counties in seasons when several days of continuous rainy weather occur during the period January to April. It has been observed as early as November. Navel oranges grown there, due to undefined factors, are particularly susceptible to this form of physiological breakdown. Orchards in this region are the only ones where the trouble is of outstanding commercial importance. However navel oranges from other areas show similar injury when exposed to prolonged wetting, as in an experimental rain chamber. Water spot will also develop in fresh wounds in Valencias, tangerines, grapefruit, and lemons. Kumquats, even in the absence of wounds, are very susceptible to the breakdown. A number of other fruit crops, including cherries, grapes, tomatoes, and dates, suffer important losses when rains occur during the ripening season.

This progress report is based on extensive experiments of the staff of the Agricultural Experiment Station and was summarized by the following committee of investigators: Leo J. Klotz, Chairman, A. M. Boyce, H. D. Chapman, G. E. Carman, Clarence Cree, W. W. Jones, L. A. Riehl, W. B. Sinclair, E. R. Parker, W. S. Stewart, and F. M. Turrell.

What Is Water Spot?

Water spot is a nonparasitic breakdown of the rind of citrus fruits. The most significant factor in its origin is the absorption of external water. The spongelike structure of the peel, together with the water-attracting properties of its cells, are important in the development of the malady.

Water enters the peel through places of structural weakness and through fresh wounds. If wounds callous and heal before rain comes, they do not increase water spot. Rainy periods accompanied by winds are disastrous because the mechanical injuries suffered by the fruit provide entrances for water. However, wind following rains, particularly north winds and the accompanying low humidity, dry off the fruit and check the development of water spot. Many oranges thus become marketable if the spot had not progressed beyond the initial stages before being dried. Injury of the rind by frost and hail also increases susceptibility to water spot. The rind of orange is naturally weak because cell division continues during maturation and new thin-walled cells are always present. These are zones of weakness in the rind where injury may occur and where water may enter. The extension of the rind by cell division apparently does not keep pace with the increase in volume of the fruit as it matures, during rainy periods. The absorption of water increases the fruit volume beyond the elasticity of the rind, thus causing minute cracks through which water enters very rapidly and in turn, causes larger water-soaked areas with small but readily visible cracks.

Important secondary factors in the ultimate breakdown of the fruit are the freeing inside the orange of the toxic natural oil of the rind, accompanied by brown discolorations of the affected areas, and decay by blue and green molds.

(The incidence of water spot is not correlated with density of oil glands nor the amount of rind oil nor the concentration of stomata in the orange rind. This is in agreement with anatomical research and observations that growth weaknesses and cracks and fresh mechanical and chemical injuries are the most efficient avenues for the absorption of external water.)

Water spot was first recognized as a problem in 1927, following the commercial advent in 1925 of petroleum oil sprays. These spray materials apparently so modify the rind of the fruit as to increase water absorption through its surface. There is also evidence that the rind of oil-sprayed oranges is more easily injured mechanically than that of fumigated or untreated fruit.

While anatomical studies thus far have failed to show structural differences between oil-sprayed and untreated fruit, the former has been found to absorb rain water more readily than the latter. Chemical analyses have revealed differences between oil-sprayed and unsprayed or fumigated oranges. Chemical differences have also been found between oranges from the water spot area and those from unaffected areas.

Plants grown under conditions of low light intensity, or high humidity, or generous supplies of water are known generally to develop a succulent or more tender growth than plants grown under more drastic conditions, such as high light intensity, low humidity, and limited supplies of water. Other factors which tend to produce a more tender plant are those which accelerate the plant growth, as high nitrogen supplies and favorable soil conditions. Hardening of the plant may be brought about by exposing the plant occasionally to drying conditions involving all or a few of the above factors. These factors may play a part in the severity of water spot in the region where it is most acute.

EXPERIMENTAL WORK

Studies with Oil Sprays

In the initial surveys made to determine the nature of water spot it was noted, as early as 1930, that navel oranges sprayed with miscible oil—lime sulfur were at least as free from water spot as fruit which had been fumigated or had not been treated with any insecticidal materials. It was evident from the first that the trouble developed earlier and was more severe in orchards which had been sprayed with conventional spray oils. It was thought at first that the ultimate loss from water spot was as great in fumigated groves as in those oil sprayed. Analysis showed, however, that most of the water spot occurring in fumigated groves following protracted periods of rain, arose from points of mechanical injury to the rind, such as those caused by wind.

Initiated in part by the water spot problem, extensive investigations to find a substitute for oil for control of the black scale and the citrus red mite or red spider began about 1933. During the intervening years the progress of these investigations has been reported in at least six publications.

Two comprehensive field experiments were conducted during the 1937–38 season, one of intense rainfall. Actual counting and grading of the fallen fruit in the orchards and the harvested fruit in the packing house conclusively demonstrated that a marked increase of water spot resulted from the application of petroleum oil sprays. In the oil-sprayed plots of a Washington navel grove 37 to 44 per cent of the fruit had water spot. Twenty-two per cent of the oranges sprayed with ⅔ per cent of a light oil with 10 per cent derris resins developed the injury.

Miscible oils with either lime sulfur or ammonium polysulfide caused no increase in water spot over the fumigated plots or check plots or those receiving a nonoil spray; the incidence of water spot in these plots ranged from 6 to 11 per cent. The main objection to sprays of miscible oils plus the sulfur compounds is the risk of tree injury and excessive defoliation and fruit drop, particularly if dry north winds or hot spells follow the application. Hot weather and strong winds sometimes cause a severe burning of the oranges without causing them to drop. Then there are many examples of a heavy fruit drop following lime sulfur and miscible oil even in the absence of hot weather and winds. It is one of the most unpredictable of spray combinations.

It was logical that such factors as the grade, the dosage or amount, and the type of emulsion formulation of spray oils, as well as the time of application in relation to fruit maturity, needed investigation. Surveys made following the extended rains of 1937 showed that variations in these factors did not result in appreciable differences in the incidence of water spot. Severe water spot had occurred where as little as ⅓ per cent light oil had been used in connection with applications of rotenone.

Since a solid spray deposit had been found to increase moisture loss from fruit, mainly by spreading the droplets and increasing their surface for evaporation, it was thought that possibly a zinc-copper-lime or a lime-sulfur spray might reduce the adverse effects of the previously applied oil spray by hastening fruit drying. Unfortunately the experiments showed that these materials, at least when applied in December, exerted little or no effect in reducing water spot. It was found, however, that a December application of one per cent wax emulsion following a September oil spray very slightly reduced the number of affected fruit.

Until this time the major emphasis in pest control on oranges in southern California and in that part most affected by water spot had been directed against black scale and the citrus red mite. Since then the California red scale has increased in importance as a pest of oranges in this area until consideration of control measures against it are of primary importance in pest control problems. In addition resistant red scale is known to occur in the area and must be considered. If red scale had not come into the picture as seriously as it has, some of the treatments developed as substitutes for oil for control of black scale might have alleviated the problem of water spot.

Rotenone used in oil looked promising against black scale, and the indication that less water spot develops following the use of miscible oil—lime sulfur than following fumigation suggested the possibility of combining lime sulfur and other sulfur materials with the conventional oil spray. Many trials of sulfur materials in combination with oil were made by growers and commercial organizations without success in reducing water spot. In 1940 the Citrus Experiment Station reported the results of extensive trials of low dosages of oil containing rotenone and various other toxic substances for the control of black scale. Three of the orchards used in these experiments were located within the area in which water spot is particularly prevalent. In one of these orchards, lime sulfur and various forms of sulfur used in combination with spray oils were included in the treatments. Considerable pains were taken to evaluate the occurrence of water spot in these orchards. The results were inconclusive due in part at least to the fact that no extended periods of rain occurred that season.

In laboratory and field tests derris resins dissolved in kerosene appeared promising for red scale control. However, the formulations used called for 10 per cent kerosene, and it was found in field use that the amount of kerosene accumulating around the trunk of the tree at the soil line from spray run-off could girdle the tree. This hazard was sufficiently great to make further use of these sprays inadvisable.

In addition to the studies on rotenone the search for other means of increasing the efficiency of oil, or for substitutes for oil, for red scale and citrus red mite was intensified. The results of these investigations were reported by the Citrus Experiment Station in ten publications released between 1940 and 1944. Reports of the results of tests of DN (dinitro-cyclo-hexyl phenol) against the citrus red mite were issued in 1942. This material has had considerable commercial use.

Search for Water Repellant

Because of the possibility that a water-repellant material might reduce loss from water spot, tests were made with many types of coverings. An application of water wax made during the 1941–42 navel harvest season not only failed to lessen water spot but induced severe drop of leaves and fruit. During the season of 1945–46 eight other formulations of wax emulsions, with and without the addition of bentonite, did not protect oranges in rain chamber tests. These materials included emulsions of paraffin plus carnauba wax, orange wax plus carnauba, carnauba alone, and orange wax alone. A heavy coating of road wax (Hunt Process Wax) protected oranges under rain chamber conditions but so effectively excluded air that it started internal fruit breakdown and spoilage.

Last year still further studies of coatings for possible protection against water spot were made. Little encouragement was obtained from the use of 68 different coatings including wax emulsions, resins, silicones, metallic salts of fatty acids and rubber latex materials in various solvents. Why these so-called water-insoluble materials failed to inhibit the absorption of water is not understood, but is not surprising in view of the fact that a block of wood even after being boiled in paraffin and given a heavy coating of the wax, will absorb water when immersed.

As already indicated, even if a material successfully waterproofs the fruit, injury to the tree in the form of direct burning, defoliation, and fruit-drop, and the development in the oranges of off-flavors and breakdown could preclude its use. Search is being continued for a material that will exclude water but permit passage of gases and thus not interfere with normal respiration in the fruit.

Tests with Organic Chemicals

While possibilities for the use of synthetic organic chemicals as insecticides had been recognized for some time and a limited number of materials investigated, the advent of DDT in 1943 furnished the spark for impetus in this direction. A very extensive laboratory and field program to investigate the use of synthetic organic chemicals for the control of citrus pests has been under way in the Citrus Experiment Station for several years. Some idea of its magnitude may be gained from the fact that about 1700 different compounds have been evaluated in laboratory tests against red scale and the citrus red mite since 1946.

Materials showing promise against the citrus red mite in the laboratory have been tested under field conditions. In this program 150 different substances tried in as many as 1200 varied formulations have been applied in approximately 2000 plots in more than 200 orchards throughout southern California. In all cases actual mortality counts have been made to evaluate the degree of control obtained. Some of the results have been encouraging. The most promising material is K-1875 [bis (p-chlorophenoxy) methane] reported in 1946. Commercial use has indicated the need for further investigations of this material.

The possibility of alleviating the water spot problem through the use of insecticide materials which do not predispose the fruit to this type of injury is also dependent upon finding toxicants which provide adequate red scale control and which are practical and safe to apply to trees. Without exception all of the materials which have demonstrated any measurable effectiveness against red scale in the laboratory investigations cited above have been tested exhaustively in the field. During the past two years alone over 45 candidate scalecides have been tested under field conditions in a wide selection of dosage ranges and formulations. Of this number only two materials, DDT and parathion, have shown sufficient promise to justify extensive field studies on all commercial varieties of citrus under most seasonal and regional conditions. Particular attention has been given to the application of these two materials to navel oranges growing in the areas where the greatest water spot susceptibility occurs.

While the incidence of water spot in field plots during the past several winters has been too low to make observations significant, rain chamber tests in which fruits from trees sprayed with a two-application schedule of DDT-kerosene have been exposed to continuous wetting for 96 hours, indicated 46 per cent (1947–48) to 58 per cent (1946–47) less water spot than oil-sprayed fruits from the same groves. While red scale control with DDT-kerosene has been entirely adequate on navels, the treatment has proven to be restrictively expensive both because of the cost of materials and the extra application and because of the need for subsequent red spider treatments.

In rain chamber tests thus far limited to the 1947–48 season, parathion-sprayed fruits showed 43 per cent less water spot injury than comparable oil-sprayed fruits. Parathion applied as a wettable powder, without the use of any oil or solvents, continues to show outstanding promise for red scale control and comprehensive tests with this material as well as with DDT are in progress.

Studies to Improve Tree and Fruit Reaction to Oil

New Spray Oils. In recognition of its over-all merits in citrus pest control, a comprehensive investigation of petroleum oil has been undertaken to study means of improving insecticidal efficiency and minimizing or eliminating those factors causing unfavorable tree and fruit responses.

Spray Pressures. There has been a tendency on the part of spray operators to use higher pressures and the feeling arose that this contributed to the incidence of water spot. The California Fruit Growers Exchange investigated this factor in an orchard at La Verne during the 1943–44 season. They concluded that variation of the pressure of the spray stream did not cause appreciable differences in the amount of water spot.

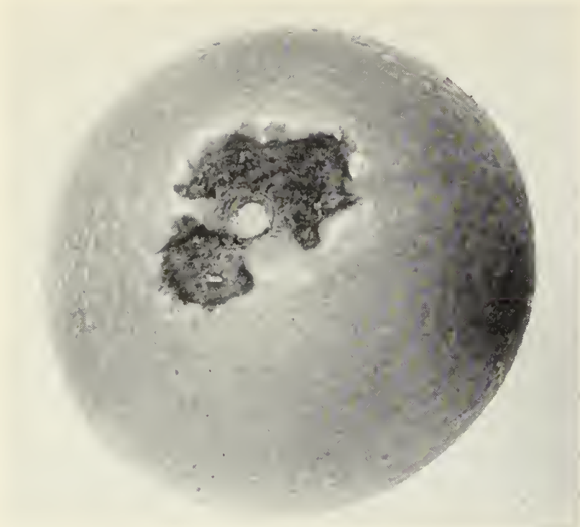
Time of Spraying. Beginning in about 1945 many growers picked their navel oranges as early as possible and attempted to get the oil spray on before blossom time. Field observations indicate that pest control is generally less efficient and that adverse effects of oil are often more pronounced in trees sprayed with oil early in the spring.

Fertilizer Practice. Results of extensive fertilizer experiments in progress since 1937 have thus far not indicated the possibility of changing to a practical degree the resistance or susceptibility to water spot by differential applications to soil of N, P, K, organic matter and soil amendments. No reduction by sprays of zinc and manganese has been observed. While slight increases in water spot resulted from heavy applications of nitrogen, and some decreases from heavy applications of phosphates, there was a large amount of the breakdown in all the field plots when conditions favored its development. Chemical analyses of leaves taken from 221 groves in the water spot area (representing high, moderate, and low incidences of water spot) showed that groves not seriously affected had a lower content of nitrogen in their leaves than those severely affected.

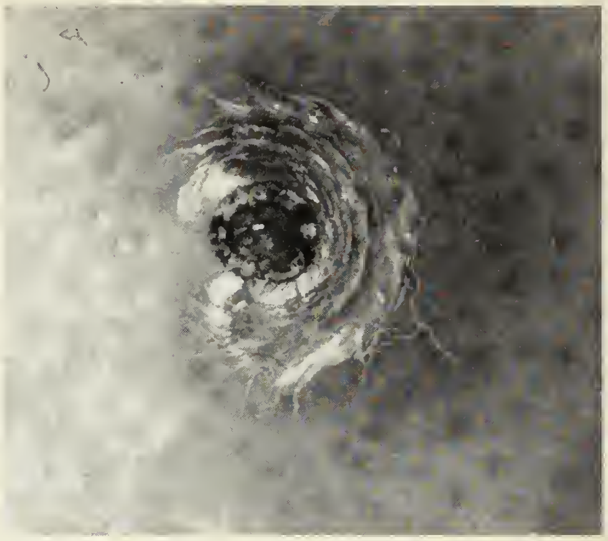
Girdling. Commercial girdling of trees in a Highgrove orchard apparently had no effect on development of the trouble in rain chamber tests. However, girdling by removing a 3/8-inch strip either above or below the bud union, which, of course, eventually killed the trees, increased the incidence of water spot in Riverside navels threefold. Girdling increased the concentration of soluble solids, of H-ion concentration, and of acids in the pulp juice; these are factors which increase the water absorbing power of the fruit.

Fruit Varieties. A comparison in the rain chamber of 31 varieties of citrus revealed that the Golden Nugget and Australian varieties of navel showed resistance. These are

TYPICAL FORMS OF WATER SPOT



Stem-end form of water spot, prevalent following cold weather and ice formation on fruit.



Navel end form of water spot, in initial stages. This closeup view clearly shows cracks in fruit surface.

Navel and side spot forms: *top row left and center,* typical "blistering"; *right,* beginning of collapse; *bottom row,* advanced stages of collapse of rind, and beginning of blue-green mold development.

not, however, desirable commercial varieties of oranges. In 1946, 60 orange varieties were tested. All except a few rather uncommon, and probably undesirable orange varieties, were susceptible. Rain chamber tests indicated that the various stocks, including sweet orange, sour orange, rough lemon, and trifoliate orange, had no effect on susceptibility of navel oranges to water spot.

Growth Regulators. The possibility of changing fruit growth with growth regulators to increase resistance of the rind to water spot has been under test since 1946. A preliminary test with Riverside navels showed that fruit treated on May 31, 1946 with a water solution of 75 or 225 ppm of 2,4-D did not develop water spot in the rain chamber when tested in January, 1947; however, owing to the excessive amounts of 2,4-D used, these fruits were of poor quality and had little commercial value.

Following up this lead, a plot was established at Azusa on July 7, 1947. Concentrations of 2,4-D ranging from 8–72 ppm were applied on that date. All the trees were oil sprayed on August 22. When the fruit was tested in the rain chamber on December 17, 1947 water spot was found to be reduced in proportion to the amount of 2,4-D applied. It is believed this reduction is due largely to the effect of the growth regulator in delaying maturity, although some of the other modifications in fruit growth may contribute to the decrease. The chemical maturity index, soluble solids—acid ratio, as well as visual observation of green color indicated that the 2,4-D sprayed oranges were less mature than the nonsprayed fruits. No recommendations on this treatment can be made at present.

SUGGESTIONS FOR CONTROL

Problems for Research:

1) The greatest need for control of water spot in the susceptible plantings is to discover or develop nonoil sprays or new oil sprays that will control insect pests. Further work with DDT, Neotran, parathion, and other insecticides may demonstrate whether or not these materials can be substituted for oil sprays. If they can, water spot should revert to a much less serious problem. If objectionable oil sprays cannot be replaced, other corrective measures will be necessary in the affected area.

2) The possibility of delaying fruit maturity and modifying rind structure with plant growth regulators and thus decreasing water spot, has been indicated in preliminary experiments.

What the Grower Might Do:

3) Where and when feasible, fumigation with HCN should be used instead of oil spray for control of scale insects.

4) The navel crop in the limited area affected might be harvested and marketed early in the season before advanced maturity and greatest susceptibility to water spot.

5) Topworking to Valencias or to other varieties on which water spot is not a commercial problem may be feasible under some circumstances.

6) Reduce humidifying effect of cover crops by mowing, or by adopting oil control of weeds or clean culture practices.

7) Adopt a conservative program of nitrogen fertilization.

In order that the information in our publications may be more intelligible it is sometimes necessary to use trade names of products or equipment rather than complicated descriptive or chemical identifications. In so doing it is unavoidable in some cases that similar products which are on the market under other trade names may not be cited. No endorsement of named products is intended, nor is criticism implied of similar products which are not mentioned.

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